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Synthesis of nanocrystalline diamond for applications in high temperature electronics

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High-temperature electronics and MEMS (Micro-Electro-Mechanical Systems) based on polycrystalline diamond (PCD) are promising because of its wide band gap, high thermal conductivity, and large carrier mobility. To take advantage of this opportunity, research was undertaken to develop techniques for the synthesis of both undoped and doped high quality PCD films with good surface flatness suitable for the fabrication of high temperature electronics and MEMS devices. One way to fabricate smooth films is to decrease the grain size because diamond films with large grain size bring forth problems in contact formation and device fabrication due to the large surface roughness. Consequently, there is a need to fabricate nanocrystalline films with small grain size and good smoothness. In addition, the electrical properties and conduction mechanisms in nanocrystalline diamond (NCD) films have not been sufficiently analyzed. This study also aims at achieving high resistivity nanocrystalline diamond films and to study the electrical conduction mechanism. Electrical properties of the microcrystalline and nanocrystalline diamond films were measured over a range of temperatures by fabricating capacitors using a metal-insulator-metal (MIM) configuration that could withstand temperatures up to 600^{o}C. Typical electrical resistivities of MCD were ~10^{12} Ω.cm while the dielectric constant was near 5.6, which was representative of natural diamond. For NCD, the electrical resistivities were of ~10^{11} Ω.cm was obtained, which was eight orders of magnitude higher than values reported by other researchers. A lower dielectric constant of 5.2 was obtained for the NCD. The electrical conduction mechanisms in undoped MCD, NCD, and nitrogen-doped films were studied. The Hill's conduction mechanism was dominant in MCD and NCD films due to the deep-level traps present, which contributed to grain-boundary conduction. The average distances between the trap sites were found to be 11 nm for the MCD, and 5 nm for the NCD were estimated. These related to the hopping conduction across impurities present in the grain boundaries. These impurities were attributed to graphite in the PCD films. The nitrogen-doped diamond films were processed to fabricate a metal-insulator-semiconductor (MIS) structure. The resistivity of a 1% nitrogen-doped diamond was $2.8x10^{7}$ Ωcm. The space-charge-limited-conduction mechanism was suggested for the nitrogen-doped diamond films due to holes injected from the p-type silicon into the n-type diamond layer, and the injected holes played a role of the current carriers.

Biography

Rahul Ramamurti expertise in plasma physics, thin film materials, nano technology, Chemical Vapour Deposition (CVD), Physical Vapour Deposition (PVD), process development of diamond, DLC, SiC, SiCN coatings for several applications.He has a PhD in Materials Science and Engineering from the University of Cincinnati and Post Doctoral Research experience at Michigan State University/Fraunhofer U.S.A. He has worked in companies involving DLC coatings for the oil and gas industry, single crystal diamond for gem applications and oxide coatings for optical filter applications.

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